The Astronomical Journal, 143:124 (6pp), 2012 May doi:10.1088/0004-6256/143/5/124

SPECKLE INTERFEROMETRY AT THE U.S. NAVAL OBSERVATORY. XVIII

Brian D. Mason, William I. Hartkopf, and Elizabeth A. Friedman[1]
U.S. Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC 20392-5420, USA;
bdm@usno.navy.mil, wih@usno.navy.mil, efriedman09@ucla.edu
Received 2012 March 6; accepted 2012 March 20; published 2012 April 16

ABSTRACT

The results of 2490 intensified CCD observations of double stars, made with the 26 inch refractor of the U.S. Naval Observatory, are presented. Each observation of a system represents a combination of over 2000 short-exposure images. These observations are averaged into 1462 mean relative positions and range in separation from 0″.56 to 71″.80, with a mean separation of 14″.81. This is the 18th in this series of papers and covers the period 2011 January 3 through 2011 December 18. Also presented are four pairs which are resolved for the first time, thirteen other pairs which appear to be lost, and linear elements for four additional pairs.

Key words: binaries: general – binaries: visual

Online-only material: color figure, machine-readable and VO tables

1. INTRODUCTION

This is the 18th in a series of papers from the U.S. Naval Observatory's speckle interferometry program, presenting results of observations obtained at the USNO 26 inch telescope in Washington, DC. Over 26,000 measures have now resulted from this program since its inception by Charles Worley, Geoff Douglass, and colleagues in the early 1990s (see Douglass et al. 1997).

From 2011 January 3 through 2011 December 18, the 26 inch telescope was used on 59 of 242 (24%) scheduled nights. While most nights were lost due to weather conditions, time was also lost due to equipment upgrades, mechanical issues, and to a lack of observing personnel. All observations were obtained with the secondary camera, described by Mason et al. (2007).

Most of the systems observed with this camera have separations well beyond the regime in which there is any expectation of isoplanicity, so we classify the observing technique for all of these measures as just "CCD astrometry," rather than speckle interferometry. Despite this classification, there is an expectation that the resulting measurements have smaller errors than classical long focus CCD astrometry. Each measurement is the result of many hundreds of correlations per frame, and up to several thousand frames per observation. This ensemble of observations is then processed and measured using the conventional directed vector autocorrelation techniques used by the CHARA and USNO speckle teams for over 20 years.

While individual nightly totals varied substantially from 3 to 101 objects per night (mean 42.2), the results yielded 2490 observations and 2610 resolutions. After removing marginal observations, calibration data, and tests, a total of 2396 measurements remained, including measures obtained in 2007–2008. These were grouped into 1462 mean relative positions, including 23 confirmations of double stars with only one previous observation.

Observing list construction and calibration procedures remain the same as those described for the "secondary" camera in Mason et al. (2007). This method also allowed us to use double stars to evaluate system accuracy and precision by observation of well-characterized orbital or linear solutions. Evaluation of the ensemble of the tabulated $O - C$ in Table 3 allows the error to be grossly characterized as $\pm 1^{\circ}.0$ in position angle and $\pm 1\% \rho$ in separation.

2. RESULTS

2.1. New Pairs

Table 1 presents coordinates and magnitude information from CDS[2] for four pairs which are measured here for the first time. All were observed as closer components to known systems or pairs in the same field of view. Column 1 gives the coordinates of the primary of the pair. Column 2 is the discoverer designation (where WSI = Washington Stellar Interferometer) number. Columns 3 and 4 give the visual magnitudes of the primary and secondary from Aladin for these pairs, and Column 5 notes the circumstance of the discovery. The mean double star positions (T, θ, and ρ) of these systems are given in Table 2.

2.2. Measures of Known Pairs

Table 2 presents the mean relative position of the members of 1462 systems having no published orbital or rectilinear elements. The first two columns identify the system by providing its epoch-2000 coordinates and discovery designation. Columns 3 through 5 give the epoch of observation (expressed as a fractional Besselian year), the position angle (in degrees), and the separation (in seconds of arc). Note that the position angle has not been corrected for precession and is thus based on the equinox for the epoch of observation. Objects whose measures are of lower quality are indicated by colons following the position angle and separation. These lower-quality observations may be due to one or more of the following factors: close separation, large Δm, one or both components very faint, a large zenith distance, and poor seeing or transparency. They are included primarily due to either the confirming nature of the observation or the number of years since the last measured position. The sixth column indicates the number of independent measurements (i.e., observations obtained on different nights) contained in the mean, and the seventh column flags any notes.

[1] Summer intern.

[2] Magnitude information is from the Aladin sky atlas, operated at CDS, Strasbourg, France.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
MAY 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	
Speckle Interferometry At The U.S. Naval Observatory.XVIII	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Naval Observatory,3450 Massachusetts Avenue< NW,Washington,DC,20392**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

The Astronomical Journal, 143:124 (6pp), 2012 May

14. ABSTRACT

The results of 2490 intensified CCD observations of double stars, made with the 26 inch refractor of the U.S. Naval Observatory, are presented. Each observation of a system represents a combination of over 2000 short-exposure images. These observations are averaged into 1462 mean relative positions and range in separation from 0. 56 to 71. 80, with amean separation of 14. 81. This is the 18th in this series of papers and covers the period 2011 January 3 through 2011 December 18. Also presented are four pairs which are resolved for the first time, thirteen other pairs which appear to be lost, and linear elements for four additional pairs.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Table 1
New WSI pairs

Coordinates α, δ (2000)	Discoverer Designation	$\text{Mag}_{\text{primary}}$ (V)	$\text{Mag}_{\text{secondary}}$ (V)	Note
044046.06+205221.0	WSI 43	9.9	11.3	a
055614.22+435534.9	WSI 44 CD	10.7	12.0	a
061554.30+000011.1	WSI 45 AB	12.1	14.1	b
210950.29+364551.7	WSI 50 AB	9.9	12.5	b

Notes.
[a] Appears to be a common proper motion companion. Measure confirmed with Two Micron All Sky Survey matching.
[b] Physicality status unknown, but closer than the known pair, now designated AC, measured here as well.

The 1462 measurements in Table 2 have a mean separation of 14.″91 and a median separation of 9.″48.

The most common note indicators are either "C," indicating a confirming observation, or a number (N) indicating the number of years since the system was last measured. This is only given for systems with $N \geqslant 50$ years. Twenty-three systems are confirmed here. Since priority is given to both unconfirmed systems and to systems not observed recently, the time since the last observation can be surprisingly large; for the systems in Table 2 the average time since the last observation is 11 years (59 years for those measures of reduced accuracy). Twenty systems had not been observed in 50 years or more and twelve had not been observed for at least a century. The maximum such time span was 115 years for SEI1476, SEI1431, and SEI1428 (Scheiner 1908). The long delay in confirming these historic pairs was simply due to poor coordinates—most had only arcminute-precise published coordinates, precessed without proper motion correction from the original coarse epoch-1820 α and δ. Also included in Table 2 are seven measures from 2007. These pairs, originally slated for Mason et al. (2008), were very different from the historical measures and were withheld until those large differences could be verified.

2.3. Orbit and Linear Calculations

Table 3 presents the mean relative positions for 131 systems with published orbital determinations or linear solutions. The first six columns are identical to the corresponding columns of Table 2. Columns 7 and 8 give $O - C$ residuals (in θ and ρ) to the determination referenced in Column 9. The reference is either to a published orbit or linear calculation. Notes follow in Column 9. The objects in Table 3 tend to be more frequently observed than those in Table 2. Here mean and median separations of 15.″33 and 20.″66 are determined, with a mean time interval since the last observation of only 3.6 years. In nine cases, it is not possible to yet ascertain the preferred determination and additional residual lines are provided.

2.3.1. New Linear Elements

In her work as an intern in Summer 2011 one of us (E.A.F.) identified pairs which were possibly linear but for which current data were insufficient for accurate determination (see Friedman et al. 2011, 2012). These objects were flagged for observation and following this observing year additional data now allow these elements to be determined. Their apparent linear relative motions suggest that these pairs are either composed of physically unrelated stars or have very long orbital periods. Linear elements to these doubles are given in Table 4, where

Table 2
ICCD Measurements of Double Stars

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000. +	θ (°)	ρ (″)	n	Note
00001+5400	ES 704	11.918	116.1	4.38	2	
00011+6336	MLB 240	11.853	42.1	5.99	2	C
00039+6041	PTT 19	11.853	3.5	15.33	2	95,C
00040+6050	HJ 1930	11.853	166.4	10.95	2	
00043+4235	HJ 1932 AB	11.790	306.5	7.11	2	
00043+4235	WAL 4 AC	11.790	187.9	46.81	1	
00046+4723	ES 1293	11.643	185.3	5.93	2	
00049+4939	ES 864	11.790	167.8	9.03	1	
00083+2029	BOW 3	11.880	47.5	3.18	3	
00088+5439	STI 1283	11.918	125.1	13.05	2	

Notes.
A: While it does not match the discovery measure, it matches the recent measures well.
B: Typo or identification error in Espin (1908) measure. Both these match the discovery measure of Herschel (1831) quite well.
C: Confirming observation.
D: Large position change, but identification not in doubt.
E: Incomplete orbital elements in Hopmann (1960).
F: First resolution of a new pair. See Table 1.
G: Wider pair listed by discoverer and not in earlier WDS editions. Discovery designation added recently, so not in the discoverer's ordinal list.
$N = 51$–115: Number of years since the last measure.

(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.)

Columns 1 and 2 give the WDS and discoverer designations and Columns 3–9 list the seven linear elements: x_0 (zero point in x, in arcseconds), a_x (slope in x, in $''$ yr^{-1}), y_0 (zero point in y, in arcseconds), a_y (slope in y, in $''$ yr^{-1}), T_0 (time of closest apparent separation, in years), ρ_0 (closest apparent separation, in arcseconds), and θ_0 (position angle at T_0, in degrees). See Hartkopf & Mason (2011) for a description of all terms. Table 5 gives orbital ephemerides for each pair over the years 2010 through 2035, in five-year increments. Columns 1 and 2 are the same identifiers as in Table 4, while Columns 3 + 4, 5 + 6, etc., through 11 + 12 give predicted values of θ and ρ, respectively, for the years 2010.0, 2015.0, etc., through 2030.0. As an example of these, Figure 1 provides a plot of the new linear solution and data for WDS 00455+1232 = HJ 7. Micrometric observations are indicated by plus signs and asterisks and CCD measures by triangles. "$O - C$" lines connect each measure to its predicted position along the new linear fit (shown as a thick solid line). The dashed line indicates the time of closest apparent separation. The axis indicates the scale in arcseconds. Direction on the sky and the relative motion of the secondary is indicated at lower right.

2.4. Double Stars not Found

Table 6 presents 13 systems which were observed but not detected. Possible reasons for non-detection include orbital or differential proper motion making the binary too close or too wide to resolve at the epoch of observation, a larger than expected Δm, incorrect pointing, and misprints and/or errors in the original reporting paper. It is hoped that reporting these will encourage other double star astronomers to either provide corrections to the USNO observations or to verify the lack of detection. Notes to some of these pairs, highlighting some possible reasons for non-detection, are appended to the table.

Table 3
Measurements of Systems with Orbits or Rectilinear Solutions

WDS Desig. $\alpha\delta$ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	$O-C$ (°)	$O-C$ ($''$)	Reference	Note
00032+4508	HJ 1927	11.643	72.8	9.83	2	−0.1	−0.05	Hartkopf & Mason (2011)	
00057+4549	STT 547 AB	11.643	186.4	6.02	2	−0.7	0.08	Popovic & Pavlovic (1996)	
						−0.3	−0.02	Kiyaeva et al. (2001)	
00063+5826	STF 3062	11.662	350.4	1.45	1	0.5	−0.10	Söderhjelm (1999)	
00159+5233	ES 865 AB	11.662	102.2	4.17	2	0.1	0.07	Hartkopf & Mason (2011)	
00277−1625	HJ 1968 AB	11.009	234.1	35.35	1	0.3	−0.03	Hartkopf & Mason (2011)	
00403+2403	BU 1348 BC	11.643	246.7	32.85	2	−0.6	−0.24	Table 5	
00455+1232	HJ 7	11.643	304.3	26.29	1	−0.1	0.11	Table 5	
00464+3057	STF A 1	11.662	46.5	47.02	1	0.1	−0.26	Hartkopf & Mason (2011)	
01052+4354	A 1810	11.643	182.1	2.97	2	0.3	−0.04	Hartkopf & Mason (2011)	
01172+0201	HDO 45	11.643	103.2	37.99	2	0.0	−0.07	Table 5	
01207+4620	STF 112 AB	11.643	336.5	19.17	2	0.2	0.10	Hartkopf & Mason (2011)	
01374+5838	STT 33 AB	11.662	77.5	26.64	1	0.2	−0.22	Hartkopf & Mason (2011)	
01395+3216	SEI 19	11.919	347.6	18.86	2	0.2	0.20	Hartkopf & Mason (2011)	
01404+3420	FOX 118 AC	11.018	137.5	63.24	1	0.5	0.35	Hartkopf & Mason (2011)	
01404+3420	STF 143 AB	11.018	319.0	46.03	1	0.2	0.02	Hartkopf & Mason (2011)	
01459+7142	HJ 1089 AB	11.643	89.2	26.44	1	0.2	−0.14	Table 5	
01522+6627	STF 167	11.662	313.9	31.30	1	0.2	−0.02	Hartkopf & Mason (2011)	
01581+4123	S 404 AB	11.018	83.6	28.98	1	0.0	0.15	Hartkopf & Mason (2011)	
02011+3518	STF 197 AB	11.018	232.7	37.30	1	0.0	−0.58	Hartkopf & Mason (2011)	
02157+6740	ENG 10 AB	11.037	328.2	23.83	1	0.6	0.03	Hartkopf & Mason (2011)	
02157+6740	ENG 10 AB	11.796	327.6	24.25	3	0.5	0.04	Hartkopf & Mason (2011)	
02201+5922	SMA 32	11.037	122.2	18.12	2	0.3	0.04	Hartkopf & Mason (2011)	
02407+6117	STF 284 AB	11.701	190.4	6.82	2	0.0	−0.06	Hartkopf & Mason (2011)	
02578+4431	STF 328 AB	11.053	305.8	15.06	1	0.3	0.04	Hartkopf & Mason (2011)	
03047+6346	STF 335	11.037	161.5	21.55	2	0.4	0.09	Hartkopf & Mason (2011)	
03053+4254	HJ 2171	11.010	308.1	16.09	2	1.8	−0.59	Hartkopf & Mason (2011)	
03122+3713	STF 360	11.010	125.8	2.79	3	−0.2	−0.04	Mason et al. (2004)	
						0.5	−0.07	Hartkopf & Mason (2011)	
03162+5810	MLB 115 AB	11.662	3.6	5.02	2	0.3	0.05	Zirm (2008)	
03207+4641	BU 1294	11.643	239.0	8.54	2	0.4	−0.01	Hartkopf & Mason (2011)	
03298+8402	STF 343 AB	11.037	327.5	34.92	1	1.0	−0.11	Hartkopf & Mason (2011)	
03314+0131	HJ 2194	11.919	120.8	34.25	1	0.2	−0.19	Friedman et al. (2011)	
03320+6735	STT 54 AB	11.662	0.9	22.09	1	−0.2	0.11	Hartkopf & Mason (2011)	
03345+5335	HJ 2192 AB	11.662	239.2	30.37	1	0.1	0.06	Hartkopf & Mason (2011)	
03440+3822	STF 434 AB	11.010	82.8	33.40	1	0.4	−0.23	Hartkopf & Mason (2011)	
03480+3821	STF 447	11.010	156.7	31.76	1	0.2	0.08	Hartkopf & Mason (2011)	
04016+3840	STF 476 AB	11.010	289.6	25.66	2	0.4	0.02	Hartkopf & Mason (2011)	
04027+5428	AG 307	11.662	328.5	13.11	2	−0.2	−0.07	Hartkopf & Mason (2011)	
04111−1826	UPT 1	11.010	94.6	3.45	2	−0.1	−0.15	Hartkopf & Mason (2011)	
04204+2721	SHJ 40 AB	11.064	257.6	48.30	1	−0.1	−0.20	Hartkopf & Mason (2011)	
04341+5301	ES 2608 AB	11.952	355.6	20.14	2	0.1	0.03	Hartkopf & Mason (2011)	
04433−0937	STF 588 AC	11.092	268.6	44.82	1	0.1	−0.10	Hartkopf & Mason (2011)	
04472+2027	KU 85	11.054	32.2	33.44	1	0.1	−0.03	Hartkopf & Mason (2011)	
04588+4408	STF 613 AB	11.054	99.9	11.86	1	0.5	0.11	Hartkopf & Mason (2011)	
04599+0031	J 47	11.092	297.2	5.65	1	−0.1	−0.26	Hartkopf & Mason (2011)	
05154+3020	AG 92 AB	11.149	334.8	24.99	1	−0.2	0.05	Hartkopf & Mason (2011)	
05276−0038	BAL 670	11.946	302.8	10.83	2	−0.9	−0.14	Hartkopf & Mason (2011)	
05407−0157	STF 774 AB	11.946	164.8	2.45	1	−1.4	0.24	Hopmann (1967)	
05429+0001	STF 782 AB	11.947	305.5	47.05	1	0.2	0.12	Hartkopf & Mason (2011)	
05487−0856	A 499 AB	11.947	230.9	12.28	1	−2.8	−0.13	Hartkopf & Mason (2011)	
06096+0540	STF 859 AB	11.802	242.3	44.85	1	0.2	−0.17	Hartkopf & Mason (2011)	
06121−1309	STF 875	11.947	323.2	4.42	2	−0.6	0.04	Hartkopf & Mason (2011)	
06195+1220	STF 892	11.966	40.7	39.41	2	0.1	−0.05	Friedman et al. (2011)	
06212+2108	S 513 BC	11.136	103.0	14.22	1	−2.0	0.39	Hartkopf & Mason (2011)	
06231−1553	STN 13 AB	8.138	322.0	6.97	1	1.2	−1.35	Hartkopf & Mason (2011)	
06231−1553	STN 13 AB	11.794	322.1	8.33	2	1.1	−0.06	Hartkopf & Mason (2011)	
06269+2951	HJ 388	11.966	141.9	25.80	2	0.9	−0.32	Friedman et al. (2011)	
06486−0405	A 58 AB	11.947	161.1	5.02	2	0.3	−0.01	Hartkopf & Mason (2011)	
07143+1546	STF 1047 A,BC	11.816	29.9	23.97	2	−0.3	0.27	Hartkopf & Mason (2011)	
07375−0059	HO 35 AC	11.264	219.3	34.79	1	−1.7	−0.36	Hartkopf & Mason (2011)	
07399+2643	HJ 765 AB	11.136	229.6	21.58	3	−0.8	0.41	Hartkopf & Mason (2011)	
07399+2643	HJ 765 AC	11.136	301.2	47.77	1	−0.1	−0.08	Hartkopf & Mason (2011)	
07492+0605	HJ 61	11.264	166.6	18.52	1	0.2	0.41	Hartkopf & Mason (2011)	

Table 3
(Continued)

WDS Desig. $\alpha\delta$ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	$O-C$ (°)	$O-C$ ($''$)	Reference	Note
07534+2050	HJ 432 AB	11.264	277.1	14.86	1	0.0	−0.01	Hartkopf & Mason (2011)	
08047+1204	STF 1179 AB	11.947	201.5	23.43	3	0.0	0.15	Hartkopf & Mason (2011)	
08122+1739	STF 1196 AB	11.816	33.4	0.99	1	2.2	−0.09	Mason et al. (2006)	
08122+1739	STF 1196 AB,C	11.816	66.6	6.22	2	−1.0	0.30	Heintz (1996)	
09522+0313	BAL 2368	11.264	79.1	50.51	1	0.2	−0.26	Hartkopf & Mason (2011)	
10029+6847	STF 1400 AB	11.286	225.8	3.15	3	0.8	−0.33	Hartkopf & Mason (2011)	
10351+3508	STF 1449 AC	11.303	284.5	41.27	1	0.2	0.26	Hartkopf & Mason (2011)	
10470+1302	STF 1472	11.196	37.0	43.05	1	0.0	−0.11	Hartkopf & Mason (2011)	
11128+0453	J 1011	11.966	43.7	3.99	2	−0.6	−0.11	Hartkopf & Mason (2011)	
11170−0708	BU 600 AC	11.360	98.8	53.23	1	0.2	−0.18	Hartkopf & Mason (2011)	
11182+3132	STF 1523 AB	11.298	201.2	1.51	3	−0.6	−0.11	Mason et al. (1995)	
11182+3132	STF 1523 AB	11.424	200.5	1.47	4	−0.4	−0.15	Mason et al. (1995)	
11182+3132	STF 1523 AB	11.966	197.7	1.51	2	0.8	−0.12	Mason et al. (1995)	
11347+6339	STF 1550	11.286	42.3	18.38	2	0.0	0.07	Hartkopf & Mason (2011)	
11387+4507	STF 1561 AB	11.306	246.8	8.98	2	0.2	0.04	Hale (1994)	
11390+4109	STT 237 AB	11.966	243.7	1.92	1	−1.0	−0.10	Seymour et al. (2002)	
11406+2102	STF 1566	11.303	350.0	2.31	1	−0.4	−0.09	Hartkopf & Mason (2011)	
11456+0354	HJ 1196	11.265	204.1	45.62	1	0.0	0.01	Hartkopf & Mason (2011)	
12071+6905	STF 1602 AB	11.287	179.7	20.66	1	0.1	0.09	Hartkopf & Mason (2011)	
12215+2130	KU 103	11.358	339.7	23.93	2	0.1	0.06	Hartkopf & Mason (2011)	
12243+6348	STF 1640	11.303	244.1	37.67	1	0.0	−0.01	Hartkopf & Mason (2011)	
12281+4448	STF 1645	11.303	157.2	9.73	1	0.1	0.01	Hartkopf & Mason (2011)	
12383+0330	BAL 2854	11.358	301.1	16.66	1	−0.6	0.26	Hartkopf & Mason (2011)	
12383−1131	STF 1664 AB	11.240	223.7	38.02	1	0.1	−0.20	Hartkopf & Mason (2011)	
12417−0127	STF 1670 AB	11.535	195.9	1.56	2	0.3	−0.14	Scardia et al. (2007)	a
12459+1009	HJ 217 BC	11.358	140.5	45.45	1	0.0	0.04	Hartkopf & Mason (2011)	
12525+0712	HJ 2621 BC	11.358	186.9	26.31	1	−0.2	0.41	Hartkopf & Mason (2011)	
13064+7618	HJ 2644	11.287	250.8	36.49	1	0.4	−0.01	Hartkopf & Mason (2011)	
13532+0514	HJ 2690	11.358	101.8	26.03	1	0.0	−0.04	Hartkopf & Mason (2011)	
13540+3209	KU 47 AB	11.361	149.4	22.11	1	0.1	0.05	Hartkopf & Mason (2011)	
14024+4620	SWI 1	11.451	24.4	3.67	2	−1.0	0.04	Seymour et al. (2002)	
14065+7058	HJ 2703	11.287	342.7	12.43	2	0.5	0.03	Hartkopf & Mason (2011)	
14131+5520	STF 1820	11.451	121.0	2.60	2	−0.2	−0.04	Kiyaeva et al. (1998)	
14135−0900	STF 1811	11.421	332.1	42.77	1	−0.1	−0.01	Hartkopf & Mason (2011)	
14135+5147	STF 1821	11.437	235.5	13.60	1	0.7	−0.61	Kiyaeva (2006)	
14203+4830	STF 1834	11.430	103.3	1.54	2	−0.2	−0.02	Seymour & Mason (2000)	
14287−1012	STF 1847	11.421	270.3	36.67	1	0.2	−0.16	Hartkopf & Mason (2011)	
14307+8308	LDS 1800	11.287	242.7	1.83	2	13.1	0.17	Hartkopf & Mason (2011)	
14329+4126	HJ 1255	11.430	337.1	46.28	2	−0.2	0.10	Hartkopf & Mason (2011)	
16003+5856	STF 2006 AC	11.451	210.9	47.55	1	−0.2	0.13	Hartkopf & Mason (2011)	
16271+4255	BU 815 AB	11.495	327.0	24.50	1	−0.1	0.12	Hartkopf & Mason (2011)	
16566+5127	ES 2654	11.522	282.3	37.79	1	0.0	0.00	Hartkopf & Mason (2011)	
17457+3452	AG 213	11.533	175.6	22.39	1	0.1	0.07	Hartkopf & Mason (2011)	
17483+4506	SMA 79	11.525	90.8	15.46	2	0.0	0.10	Hartkopf & Mason (2011)	
17555+4108	ES 1557 AB	11.525	10.3	11.47	2	−2.8	0.42	Hartkopf & Mason (2011)	
17584+1437	STF 2253 AB	11.533	76.6	11.09	1	0.1	−0.10	Hartkopf & Mason (2011)	
18031−0811	STF 2262 AB	11.612	285.8	1.45	1	0.3	−0.15	Söderhjelm (1999)	
18032+2522	STF 2268 AC	11.533	202.0	24.12	1	−0.6	0.21	Hartkopf & Mason (2011)	
18044+0329	STF 2266 AC	11.541	200.5	50.58	1	−0.4	−0.60	Hartkopf & Mason (2011)	
18222+1126	STF 2311 AB	11.514	90.0	2.88	1	−0.5	−0.07	Hartkopf & Mason (2011)	
18317+2310	HU 321 AB	11.569	20.7	19.99	2	−0.1	−0.05	Friedman et al. (2012)	
18383+2818	SLE 361	11.628	7.6	20.03	1	−0.2	0.00	Hartkopf & Mason (2011)	
18516+3739	ES 2025 AB	11.525	351.6	24.78	2	−0.5	−0.75	Hartkopf & Mason (2011)	
19260+3555	BU 1286 AB	11.604	45.3	22.24	2	0.2	0.14	Hartkopf & Mason (2011)	
19260+3555	BU 1286 BC	11.604	209.9	20.08	2	−0.2	0.22	Hartkopf & Mason (2011)	
20014+1045	STF 2613 AB	11.762	354.5	3.47	1	2.6	−0.69	Hopmann (1973)	
20144−0603	STF 2646 AB	11.708	39.2	18.32	2	0.4	0.04	Hartkopf & Mason (2011)	
20193+2521	POU 4363	11.790	43.7	23.81	1	−0.1	0.06	Hartkopf & Mason (2011)	
20346+2914	J 565 AB	11.796	48.5	6.19	2	−0.7	0.09	Hartkopf & Mason (2011)	
21555+5232	STT 456 AC	11.853	289.8	26.58	1	−0.7	−0.08	Hartkopf & Mason (2011)	
22033+6051	STF 2860 AB	11.853	256.9	12.97	2	0.1	0.03	Hartkopf & Mason (2011)	
22166+5831	HJ 1748	11.766	309.6	5.14	3	−0.8	−0.03	Hartkopf & Mason (2011)	
22237+4054	WEI 38 AC	11.763	352.0	38.71	2	0.2	0.18	Hartkopf & Mason (2011)	
23045+3123	ES 396	11.812	303.6	34.02	2	0.0	0.23	Hartkopf & Mason (2011)	

Table 3
(Continued)

WDS Desig. $\alpha\delta$ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	$O-C$ (°)	$O-C$ ($''$)	Reference	Note
23186+6807	STF 3001 AB	11.853	222.1	3.24	2	0.1	−0.11	Docobo et al. (2003)	
23359+5132	HJ 1894 AB	11.921	214.1	24.92	1	0.2	0.13	Hartkopf & Mason (2011)	
23395+6658	HJ 1897	11.847	211.1	24.43	1	0.2	0.06	Hartkopf & Mason (2011)	
23413+4954	ES 2732	11.856	249.9	10.61	1	−0.1	0.01	Hartkopf & Mason (2011)	
23516+4205	STT 510 AB	11.763	118.8	0.56	1	1.9	−0.03	Novakovic & Todorovic (2006)	a

Notes.
[a] These are small Δm system. The orbit indicates a quadrant flip is needed; however, based on multiple high accuracy and precision determinations of the magnitudes of the pairs, the position angle in Table 3 is correct. It appears the orbits need to have their quadrants flipped instead. Residual determination assumes this.

Table 4
New Rectilinear Elements

WDS α, δ (2000)	Discoverer Designation	x_0 ($''$)	a_x ($''$ yr^{-1})	y_0 ($''$)	a_y ($''$ yr^{-1})	T_0 (yr)	ρ_0 ($''$)	θ_0 (deg)
00403+2403	BU 1348 BC	0.790	−0.04503	10.383	0.0034	1316.133	10.413	175.65
00455+1232	HJ 7	2.098	−0.04809	−5.152	−0.0196	1518.825	5.563	22.15
01172+0201	HDO 45	31.333	0.00737	−9.727	0.0237	1234.805	32.808	72.75
01459+7142	HJ 1089 AB	9.221	−0.00644	12.413	0.0048	4708.359	15.463	143.39

Table 5
Linear Ephemerides

WDS α, δ (2000)	Discoverer Designation	2010.0 θ (°)	2010.0 ρ ($''$)	2015.0 θ (°)	2015.0 ρ ($''$)	2020.0 θ (°)	2020.0 ρ ($''$)	2025.0 θ (°)	2025.0 ρ ($''$)	2030.0 θ (°)	2030.0 ρ ($''$)
00403+2403	BU 1348 BC	247.3	33.103	247.4	33.189	247.4	33.275	247.5	33.361	247.5	33.446
00455+1232	HJ 7	304.4	26.205	304.4	26.307	304.3	26.408	304.3	26.510	304.2	26.611
01172+0201	HDO 45	103.2	38.071	103.3	38.096	103.4	38.121	103.4	38.146	103.5	38.172
01459+7142	HJ 1089 AB	89.0	26.581	89.0	26.568	89.0	26.555	89.0	26.542	89.0	26.529

Table 6
Double Stars Not Found

Coordinate α, δ (2000)	Discoverer Designation	Most Recent Published Observation: Date	Position Angle θ (°)	Separation ρ ($''$)	Published Magnitude: Primary	Secondary	Notes
00156+5229	POP 158	1980	187	3.1	10.0	10.1	a
00589+3230	SEI 10	1894	100	12.4	9.5	10.0	b
00595+3202	SEI 11	1894	359	8.5	10.0	10.5	b
01149+3236	SEI 14 AC	1894	116	11.4	10.5	10.5	b
01332+3231	SEI 17	1894	193	25.8	10.3	10.5	b
01364+3209	SEI 18	1894	144	5.6	10.5	11.0	b
06053+0527	J 2014	1942	305	6.0	10.5	11.4	c
20076+1655	SLE 684 AC	1984	279	28.2	10.2	11.2	c
20144+3556	SEI 1035	1896	197	16.1	9.1	10.6	c
20313+0020	BAL 923	1895	146	3.5	10.2	10.3	c
21278+3636	ES 2127	1924	298	4.4	10.4	10.	c
23470−0921	HJ 3214	1830	275	6.0	10.	11.	c
23512+5123	ALD 7	1916	202	4.2	10.	10.	c

Notes.
[a] Companion not seen.
[b] Neither component seen on POSS plate; may be flaws on AC Potsdam plate.
[c] Neither component seen.

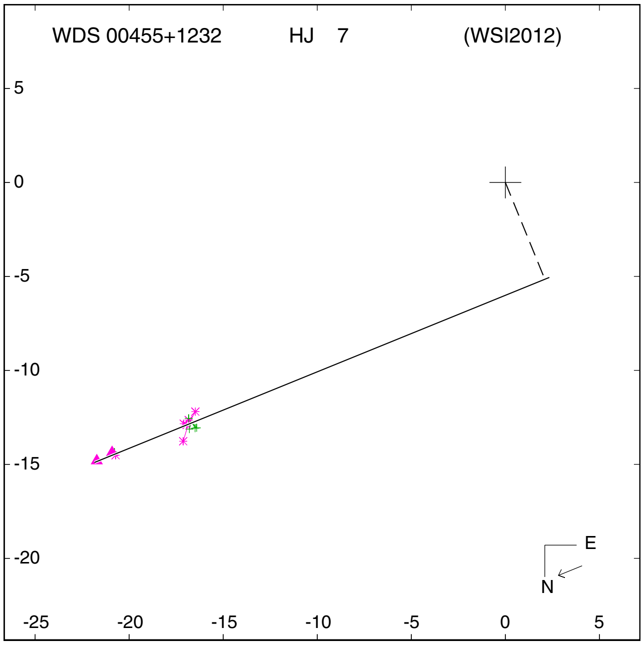

Figure 1. New linear fit for WDS 00455+1232 = HJ 7, together with all published data in the WDS database. Micrometric observations are indicated by plus signs and asterisks and CCD measures by triangles. "$O - C$" lines connect each measure to its predicted position along the new linear fit (shown as a thick solid line). The dashed line indicates the time of closest apparent separation. The axis indicates the scale in arcseconds. Direction on the sky and the relative motion of the secondary is indicated at lower right.

(A color version of this figure is available in the online journal.)

In all cases, the position angle, separation, and magnitudes are from the discoverer of the pair.

The continued instrument maintenance by the USNO instrument shop, Gary Wieder, John Evans, and Tie Siemers makes the operation of a telescope of this vintage a true delight. Thanks also to Ted Rafferty (USNO, retired) for his assistance with equipment upgrades and maintenance, and the foresight to initiate the backup camera project.

REFERENCES

Docobo, J. A., Tamazian, V. S., Andrade, M., & Melikian, N. D. 2003, AJ, 126, 1522
Douglass, G. G., Hindsley, R. B., & Worley, C. E. 1997, ApJS, 111, 289
Espin, T. E. 1908, MNRAS, 68, 202
Friedman, E. A., Mason, B. D., & Hartkopf, W. I. 2011, IAU C26 Circ., 175
Friedman, E. A., Mason, B. D., & Hartkopf, W. I. 2012, IAU C26 Circ., 176
Hale, A. 1994, AJ, 107, 306
Hartkopf, W. I., & Mason, B. D. 2011, Catalog of Rectilinear Elements, Published in Second USNO Double Star CD 2006.5, available online at http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1
Heintz, W. D. 1996, AJ, 111, 408
Herschel, J. F. W. 1831, Mem. R. Astron. Soc., 4, 331
Hopmann, J. 1960, Mitt. Sternw. Wien, 10, 227
Hopmann, J. 1967, Mitt. Univ. Sternw. Wien, 13, 49
Hopmann, J. 1973, Astron. Mitt. Wien, 13, 1
Kiyaeva, O. V. 2006, Sov. Astron. Lett., 32, 836
Kiyaeva, O. V., Kisselev, A. A., Polyakov, E. V., & Rafal'skii, V. B. 2001, Sov. Astron. Lett., 27, 391
Kiyaeva, O. V., Tokovinin, A. A., & Kalinichenko, O. A. 1998, Sov. Astron. Lett., 24, 753
Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2007, AJ, 134, 1671
Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2008, AJ, 136, 2223
Mason, B. D., Hartkopf, W. I., Wycoff, G. L., & Holdenried, E. R. 2006, AJ, 132, 2219
Mason, B. D., Hartkopf, W. I., Wycoff, G. L., et al. 2004, AJ, 127, 539
Mason, B. D., McAlister, H. A., Hartkopf, W. I., & Shara, M. M. 1995, AJ, 109, 332
Novakovic, B., & Todorovic, N. 2006, Serb. Astron. J., 172, 21
Popovic, G. M., & Pavlovic, R. 1996, Bull. Obs. Astron. Belgr., 153, 57
Scardia, M., Prieur, J.-L., Pansecchi, L., et al. 2007, Astron. Nachr., 328, 146
Scheiner, J. 1908, Pub. Obs. Potsdam 20, Pt. 2, #59
Seymour, D., & Mason, B. D. 2000, IAU C26 Circ., 141
Seymour, D., Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2002, AJ, 123, 1023
Söderhjelm, S. 1999, A&A, 341, 121
Zirm, H. 2008, IAU C26 Circ., 166